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The grant supported research on techniques for recognizing targets in visible, infrared, laser radar, synthetic aperture radar and high-range aperture radar data. Empirical probability density functions of "probe values" gives rise to a method of estimating probability that a target of known shape is present. Two-stage Constant False Alarm rate detectors were introduced to reduce the FA rate in the presence of SAR speckled images. A complete algorithm for wide-area site models using polarimetric SAR was developed. Multi-scale methods were introduced into HRR classification with an improvement in performance. Operator-theoretic methods were successfully employed in the important area of detection and location of roads and nearby targets.

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Subject: Final Report

Enclosed is the Final Report on Grant F49620-93-1-0576.

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Final Report on Grant

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The grant supported research on techniques for recognizing targets and target-related features in visible, infrared (FLIR), laser radar (LADAR), synthetic aperture radar (SAR), real aperture radar (RAR), and high range resolution (HRR) radar data, as summarized in the following paragraphs.

1. FLIR and LADAR

A probe-based approach combined with image modeling has been used to recognize targets in passive Forward Looking Infrared (FLIR) and laser radar (LADAR) imagery. A probe is a simple mathematical function which operates locally on pixel values and produces an output that is directly usable by an algorithm. An empirical probability density function of the probe values is obtained from a local region of the image, and used to estimate the probability that a target of known shape is present. Target shape information is obtained from three-dimensional Computer Aided Design (CAD) models. Knowledge of the probe values along with probe probability density functions and target shape information allows the likelihood ratio between a target hypothesis and background hypothesis to be computed. The generalized likelihood ratio test is used to accept one of the target poses or to choose the background hypothesis. An image model for infrared images and the resulting recognition algorithm were tested on both real and synthetic FLIR imagery. An image model and recognition algorithm for resolved-range and ambiguous-range LADAR imagery were also formulated and tested. A fusion recognition algorithm using collocated passive infrared and laser radar sensors was developed, and experimental results for the fusion algorithm were compared with results from the separate FLIR and LADAR algorithms. An algorithm, based on probes, for the registration of imagery from different sensor types was also developed, and registration results were obtained for FLIR-LADAR, FLIR-SAR, and FLIR-TV sensors. FLIR-SAR registration was used to allow SAR cueing of the FLIR recognition algorithm, resulting in improved performance.

2. SAR

a) CFAR detection

Traditional Constant False Alarm Rate (CFAR) detection algorithms produce many false targets when applied to single-look, high-resolution, fully polarimetric SAR images, due to the presence of speckle. A two-stage CFAR detector followed by conditional dilation has been developed for the detection of point and extended targets in polarimetric SAR images. In the first stage, possible targets are detected and false targets due to the speckle are removed by using global statistical parameters. In the second stage, the local statistical parameters are used to detect targets in regions adjacent to targets detected in the first stage. Conditional dilation is then performed to recover target pixels lost in second stage CFAR detection.

The performance of a CFAR detector will be degraded if an incorrect statistical model is adopted and the data are correlated. A goodness-of-fit test has been used to decide the appropriate distribution and the effects of decorrelation of the data are considered. Good results were obtained when this method was applied to single-look, high-resolution, fully polarimetric SAR images acquired from MIT Lincoln Laboratory.

b) Wide-area site modeling

A complete algorithm has been developed for building an approximate 2D wide-area site model from high-resolution polarimetric SAR data. Site models are useful for image analysts to delineate regions of interest and assist in further processing of data. They can also be used to register a new SAR image to an existing one of the same site, a site model or a map. Building a wide-area site model involves three steps: Detection of man-made structures, statistical segmentation of data into homogeneous regions, and grouping of detection and segmentation results. CFAR processing of single-polarization data is used for detecting bright reflectors in spatially non-homogeneous clutter. At high resolutions, non-Rayleigh magnitude distributions, such as Weibull and K, seem to be better fits to the statistics of backscatter magnitudes in the CFAR reference windows. Order Statistic CFAR detectors for Weibull and K distributions are used for the detection of man-made structures. For segmentation purposes, a circular Gaussian density is used to model correlated fully polarimetric data. Typical parameters for features such as roads, shadows, vegetation, etc. are obtained using training areas. Maximum likelihood estimates of the region labels are obtained after removing the pixels detected as possible targets by the CFAR algorithms. Thereafter, algorithm knowledge of the sensor heading and other geometric cues are used to refine the initial segmentation, to group the results, and to extract man-made structures like buildings and their shadows, as well as roads, from the images. An offshoot of these algorithms is the identification of target clusters and other areas of interest, which can be used for effective compression of SAR data.

c) Registration

A technique has been developed for registering multiple high-resolution SAR images, acquired from Unmanned Air Vehicles (UAVs) and other airborne platforms. A global affine transformation derived from the sensor acquisition parameters is used to automatically register the images, followed by a refinement to correct for translational errors. The registered SAR images are used for improving the accuracy of segmentation maps, and estimating heights of objects and target orientation angles.

3. RAR

Methods of classifying real aperture radar (RAR) returns with multiscale features have been developed. To avoid the difficulties in RAR signature classification, multiscale spectral features are estimated by a hierarchical modeling approach. In an experiment with MUSTRS data, 86 percent of the returns were correctly classified.

4. HRR

Methods of classifying HRR radar returns using multiscale features have been developed. Multiscale features are computed by hierarchical modeling approaches, and are classified by a minimum distance classifier. The multiscale classifier has been applied to both poorly aligned data and better aligned data obtained from Air Force Wright Laboratory. For both data sets, about 95 percent of the radar returns were correctly classified, showing that the multiscale classifier is robust to misalignment.

5. Roads

Detection of roads provides context for the detection of relocatable targets, which are usually located on or near roads. A robust method of detecting straight or circular pieces of road in noisy low-resolution aerial images has been developed. It first uses a local operator to detect pixels whose neighborhoods are line-like, and then applies robust estimation techniques to find sets of such pixels that lie on or near straight or circular loci. An (unbiased) ordinary least squares estimator cannot handle outlying data even for straight loci; on the other hand, conventional robust techniques for fitting circular arcs are severely affected by digitization effects and the fact that circular road segments are typically short and shallow. A new estimator has been developed that is both robust and statistically efficient.

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